Impact of Coupled Thermal-Hydrological-Chemical Processess on Seepage Into Emplacement Drifts at Yucca Mountain

Sumit Mukhopadhyay, Eric L. Sonnenthal, and Nicolas Spycher
Contact: Sumit Mukhopadhyay, 510-495-2440, SMukhopadhyay@lbl.gov

RESEARCH OBJECTIVES

Seepage refers to flow of liquid water into the emplacement drifts (tunnels) at the proposed repository site of Yucca Mountain. Seepage may enhance corrosion of waste packages, resulting in release of radioactive materials from the drifts into the surrounding rock. Understanding seepage is therefore critical for reliable prediction of repository performance. Substantial experimental and modeling studies have been undertaken to investigate seepage under ambient conditions. These studies have concluded that seepage (or its absence) is controlled by the fracture permeability heterogeneity and fracture capillary strength parameters of the repository host rock. Additionally, models have been developed to analyze the impact of coupled thermal-hydrological (TH) processes on seepage. These TH models have predicted that seepage at Yucca Mountain could occur only under considerably elevated infiltration fluxes. In this study, it is demonstrated that other factors may also influence seepage, particularly the coupled thermal-hydrological-chemical (THC) changes in the host rock.

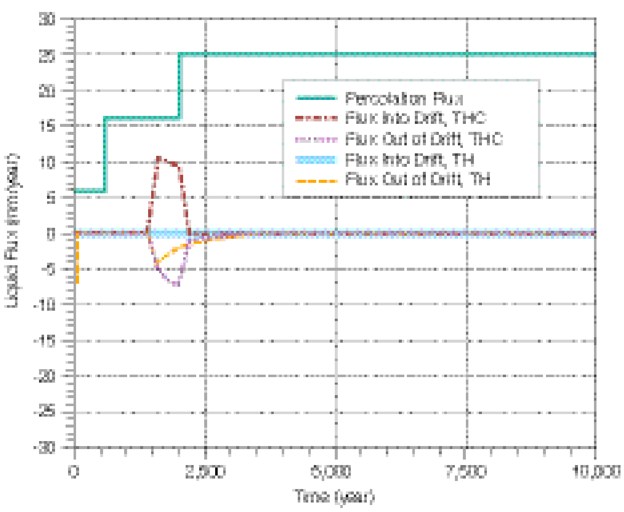

Figure 1. Seepage prediction for TH and THC simulations

APPROACH

Heat emanating from the waste keeps rock temperatures near the emplacement drifts above boiling for a considerable period of time. Boiling of water generates vapor that migrates away from the drifts, then condenses in cooler regions and drains through the fracture network, resulting in redistribution of moisture. The elevated temperature and moisture redistribution also cause changes in pore-water and gas compositions, as well as mineral dissolution and precipitation. Mineral dissolution and precipitation can result in porosity and permeability changes in the rock, which lead to altered flow paths and flow focusing. In this study, these THC processes are simulated with the TOUGHREACT reactive transport software. TH and THC simulations are performed in a two-dimensional vertical model domain extending from the ground surface to the water table. Heterogeneous fracture-permeability distributions are generated using measured air-permeability data from the host rock. The fracture capillary strength parameter of the host rock is obtained by calibrating data from ambient liquid-release tests at Yucca Mountain. Fractured rock is modeled as two separate but interacting continua, one for the rock matrix and the other for the fractures.

ACCOMPLISHMENTS

The impact of THC processes on seepage can be seen in Figure 1, which shows the amount of water entering and exiting the emplacement tunnel for one realization of the heterogeneous permeability field. Infiltration fluxes are shown with the solid green lines. The model predicts a finite amount of seepage between 1,400 and 2,000 years with the THC simulations. However, when only TH processes are simulated, no seepage is observed. (This can be attributed to the THC Processes of mineral precipitation and dissolution altering the porosities and permeabilities of the rock. They also introduce dynamic heterogeneties in the capillary characteristics. Such changes in hydrologiic properties causes focusing of flow into zones of higher permeability, leading to seepage even under circumstances not predicted by ambient or TH-only simulation.)

SIGNIFICANCE OF FINDINGS

Alternations in hydrological properties, arising from coupled THC processes, may lead to local flow focusing and seepage even under nonelevated infiltration fluxes. Further experimental and modeling studies are therefore needed to study hydrological property changes caused by THC processes.

RELATED PUBLICATION

Mukhopadhyay, S., E.L. Sonnenthal, and N. Spycher, Impact of coupled thermal-hydrological-chemical processes on seepage into emplacement tunnels in unsaturated fractured rock. Journal of Hydrology (in preparation), 2005.

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